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Interference pigments

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The present invention relates to interference pigments based on multi-coated flake-form substrates and to the use thereof, inter alia in paints, coatings, printing inks, plastics and in cosmetic formulations.

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Interference pigments are employed as lustre or effect pigments in many areas of industry, in particular in decorative coating, in plastics, in paints, coatings, printing inks and in cosmetic formulations. Pigments which exhibit an angle-dependent colour play between a plurality of interference colours are, owing to their colour play, of particular interest for automotive paints, counterfeiting-proof securities and in decorative cosmetics.

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Interference pigments generally consist of flake-form supports which are coated with thin metal-oxide layers. The optical effect of these pigments is based on directed reflection of light at the flakes which are predominantly aligned parallel. Reflection of the light at the interfaces of layers of different refractive index causes the formation of interference colours (G. Pfaff in High Performance Pigments, Wiley-VCH Verlag, Weinheim, 2002, Chap. 7, Special Effect Pigments).

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U.S. 3,331,699 describes pearlescent pigments having bright interference colours and an intense glitter effect. The pigments are based on glass flakes which are coated with a translucent, high-refractive-index metal-oxide layer. Suitable metal oxides are ZrO_2 , TiO_2 and Cr_2O_3 . The colour of the pigments here is dependent on the metal oxide selected and on the thickness of the metal-oxide layer. Many interference colours from silver via gold, violet, blue and green can be produced by different layer thicknesses. The glass composition here is not crucial for the coating with a metal oxide. In order that a coating can be achieved at all, however, the presence of a nucleating agent, such as, for example, tin dioxide or boehmite, on the glass surface is absolutely necessary.

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WO 97/46624 describes pearlescent pigments which are based on glass flakes and are coated with TiO_2 or Fe_2O_3 .

5 Lustrous pigments are only obtained if the thin metal layer on the support is very smooth and uniform. WO 97/46624 states that the coating must adhere strongly to the support in order that there is no fracture and/or detachment of the coating during processing. The user perceives inadequate adhesion of the metal-oxide layer to the support as poor mechanical stability of the pigment since the gloss drops considerably during mechanical stressing, for example due to shear forces during rubbing of the pigment in a cosmetic preparation on the skin, in the printing process, in the production of pigment granules or during pumping round the ring line of a paint shop. Even a small proportion of damaged pigment particles causes significant impairment of the coloristic properties of the pigment application.

15 Pigments from U.S. 3,331,699 and WO 97/46624 can, owing to the glass types used, only be calcined at temperatures below 600°C. However, the temperature of 600°C here does not represent a sharp limit, but instead is a compromise of technical requirements which are difficult to combine.

20 Pigments with TiO₂ layers which have been calcined at low temperature exhibit increased photoactivity, in particular on incorporation into plastic systems, and are not suitable for articles subjected to intense or long-lasting exposure to light. The causes of this are the porosity and the large active surface areas of the precipitated metal-oxide layers, which only consolidate at calcination temperatures from 700°C. This consolidation results in reduced porosity of the metal-oxide layers and at the same time in an increase in the refractive indices and thus in improved optical properties of the pigments. At higher temperatures, however, the pigments are destroyed by the considerable softening of the glass cores and associated deformation of the flakes as well as fracture and/or detachment of the coating. Even at calcination temperatures of 600°C or below, a reduction in the layer adhesion to the support can occur, impairing the mechanical stability of the pigments. Such pigments can only be employed to a limited extent in practice.

35 EP 0 753 545 B1 discloses goniochromatic lustre pigments based on high-refractive-index, transparent, non-metallic, flake-form substrates which comprise at least one layer package comprising a colourless coating hav-

ing a refractive index n of ≤ 1.8 and a reflective, selectively or non-selectively absorbent coating. Suitable substrates, such as, for example, flake-form iron oxide, BiOCl, TiO₂- or ZrO₂-coated mica, have a refractive index n of ≥ 2 . The goniochromatic lustre pigments exhibit an angle-dependent colour play between a plurality of intense interference colours and thus a pronounced colour flop, which is advantageous in many industrial applications, is frequently desired in decorative applications, but is undesired in the great majority of applications of pearlescent pigments.

WO 01/30920 discloses gold- and orange-coloured interference pigments of high hiding power which are distinguished by the fact that flake-form substrates are coated with at least two layer sequences comprising a low-refractive-index layer and a high-refractive-index layer comprising a metal-oxide mixture of Fe₂O₃ and TiO₂. The materials mentioned for the low-refractive-index coating are SiO₂, Al₂O₃, AlO(OH), B₂O₃, MgF₂, MgSiO₃ or mixtures of these oxides. However, the essential features in the case of the pigments from WO 01/30920 are the body colour and the hiding power due to the high inherent absorption of the mixed-oxide layers. Thus, only gold- and orange-coloured pigments of high hiding power are accessible. Silver-white pigments having high gloss are just as inaccessible as high-gloss pigments having bright interference colours and high transparency. There is a great demand in printing technology, in plastics, for surface coatings and in cosmetics for, in particular, silver-white pigments having improved gloss.

The object of the present invention is to provide silver-white interference pigments having high gloss and high-gloss interference pigments having bright interference colours which are mechanically stable and simple to prepare and are distinguished by further advantageous technical properties.

Surprisingly, it has now been found that interference pigments based on transparent flake-form substrates have improved gloss and exhibit more intense colours if the flakes are coated with a first layer of SiO₂, to which a high-refractive-index layer, such as, for example, titanium dioxide, titanium

suboxide, zirconium oxide, tin oxide, chromium oxide, Fe_2O_3 or Fe_3O_4 , is then applied.

5 In addition to their higher gloss, pigments according to the invention having glass flakes as support are distinguished over the coated glass flakes from the prior art by significantly improved calcination behaviour. The interference pigments according to the invention based on glass flakes can be
10 calcined at temperatures $> 700^\circ\text{C}$ without deformation or destruction of the flake structure occurring.

The interference pigments according to the invention are thus clearly superior to the pigments from the prior art not only with respect to their optical properties, such as gloss and tinting strength, but also in their technical
15 properties, such as, for example, mechanical stability and photostability.

The invention therefore relates to interference pigments based on flake-form substrates which are distinguished by the fact that they comprise

20 (A) a layer of SiO_2 having a layer thickness of 5-350 nm,

(B) a high-refractive-index coating having a refractive index n of > 1.8

25 and/or

(C) an interference system consisting of alternating high- and low-refractive-index layers

30 and optionally

(D) an outer protective layer.

35 The invention furthermore relates to the use of the interference pigments according to the invention in paints, coatings, in particular automotive paints, powder coatings, printing inks, security printing inks, plastics, ceramic materials, glasses, paper, in toners for electrophotographic printing processes, in seed, in greenhouse sheeting and tent awnings, as

absorbers in the laser marking of paper and plastics, and in cosmetic formulations. Furthermore, the pigments according to the invention are also suitable for the preparation of pigment pastes with water, organic and/or aqueous solvents, pigment preparations and for the preparation of dry preparations, such as, for example, granules, chips, pellets, briquettes, etc. The dry preparations are particularly suitable for printing inks and in cosmetics.

Suitable base substrates for the interference pigments according to the invention are colourless or selectively or non-selectively absorbent flake-form substrates. Suitable substrates are, in particular, phyllosilicates, such as natural and/or synthetic mica, talc, kaolin, flake-form iron or aluminium oxides, glass flakes, SiO_2 flakes, TiO_2 flakes, graphite flakes, synthetic support-free flakes, titanium nitride, titanium silicide, liquid crystal polymers (LCPs), holographic pigments, BiOCl and flake-form mixed oxides, or mixtures thereof. Particularly preferred substrates are glass flakes, mica flakes and Al_2O_3 flakes.

Particular preference is given to glass flakes owing to their particularly smooth surface and their very high reflectivity.

The size of the base substrates is not crucial per se and can be matched to the particular application. In general, the flake-form substrates have a thickness of between 0.005 and 10 μm , in particular between 0.1 and 5 μm . The dimension in the two other ranges is usually 1-500 μm , preferably 2-300 μm and in particular 20-200 μm . Preferred smaller particle sizes are furthermore those in the range 1-100 μm , in particular 5-60 μm and 1-15 μm .

Particular preference is given to glass flakes having an average thickness of $< 2 \mu\text{m}$. Thicker flakes generally cannot be employed in customary printing processes and in demanding finishes. The glass flakes preferably have thicknesses of $< 1 \mu\text{m}$, in particular $< 0.9 \mu\text{m}$, very particularly preferably $< 0.7 \mu\text{m}$. Particular preference is given to glass flakes having thicknesses of 0.25-0.7 μm . The diameter of the glass flakes is preferably 5-300 μm , particularly preferably 10-100 μm , furthermore 5-60 μm . Glass

flakes having these dimensions can be prepared, for example, by the process described in EP 0 289 240.

5 The glass flakes can consist of all glass types known to the person skilled in the art, such as, for example, window glass, C glass, E glass, ECR glass, Duran[®] glass, laboratory equipment glass or optical glass. Particular preference is given to E glass or ECR glass. The refractive index of the glass flakes is preferably 1.45-1.80, in particular 1.50-1.70.

10 However, the chemical composition of the glass flakes is, owing to the coating with an SiO₂ layer (layer (A)), of secondary importance for the further coatings and the resultant technical properties of the pigments. The SiO₂ coating protects the glass surface against chemical modification, such as swelling, leaching-out of glass constituents or dissolution in the aggressive acidic coating solutions.

15 During the calcination process, an intimate bond between the chemically related materials arises in the case of the glass flakes at the interface between glass body and precipitated-on SiO₂. Owing to the high softening temperature, the precipitated-on SiO₂ sheath gives the substrates the requisite mechanical stability, even in the case of calcination above 700°C. The adhesion of the high-refractive-index coating(s) following the SiO₂ layers is also very good, even above 700°C.

25 The thickness of layer (A) on the substrate can be varied in broad ranges depending on the desired effect. Layer (A) has thicknesses of 5-350 nm, preferably 5-150 nm. For control of gloss and tinting strength, layer thicknesses of 30-100 nm are preferred.

30 The SiO₂ layer may also be doped with carbon black particles, inorganic coloured pigments and/or metal particles if this doping is stable in air or under an inert gas at temperatures > 700°C. The proportion of dopant in the SiO₂ matrix is then 1-30% by weight, preferably 2-20% by weight, in particular 5-20% by weight.

The high-refractive-index coating (B) preferably consists of metal oxides and/or suboxides.

- 5 Layer (B) preferably consists of metal oxides, such as, for example, TiO_2 , ZrO_2 , SnO_2 , ZnO , Ce_2O_3 , Fe_2O_3 , Fe_3O_4 , Cr_2O_3 , CoO , Co_3O_4 , VO_2 , V_2O_3 , NiO , furthermore of titanium suboxides (TiO_2 partially reduced with oxidation states of from < 4 to 2, such as the lower oxides Ti_3O_5 , Ti_2O_3 to TiO), titanium oxynitrides, $\text{FeO}(\text{OH})$, thin semitransparent metal layers, for
10 example comprising Al, Fe, Cr, Ag, Au, Pt or Pd, or combinations thereof. The TiO_2 layer may be in the rutile or anatase modification, preference being given to rutile layers. Rutile is preferably prepared by the process from EP 0 271 767.
- 15 Layer (B) is preferably a metal-oxide layer, in particular TiO_2 , Fe_2O_3 , Fe_3O_4 , SnO_2 , ZrO_2 or Cr_2O_3 . Particular preference is given to titanium dioxide.
- 20 Layer (B) can of course also consist of a plurality of high-refractive-index layers. Layer (B) preferably consists of only one layer, furthermore of two layers.
- 25 The thickness of the high-refractive-index layers depends on the desired interference colour. The thickness of layer (B) is preferably 60-300 nm. Combination of the thin SiO_2 layer with a high-refractive-index metal-oxide layer enables, for example, interference colours from pure silver-white via gold to intense green to be obtained.
- 30 Further high- and/or low-refractive-index layers (layer C) can be applied alternately to layer (B). The number of layers is preferably two, furthermore three, four, five, six or seven layers.
- 35 In particular, interference packages consisting of high- and low-refractive-index layers on layer (B) result in pigments having increased gloss and a further increased interference colour.

Instead of layer (B), an interference system comprising alternating high- and low-refractive-index layers (layer C) can also be applied directly to the SiO_2 layer.

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The thickness of the individual layers of high or low refractive index is in turn essential for the optical properties of the pigment. For the interference pigment according to the invention, the thicknesses of the individual layers must be set precisely with respect to one another. The thickness of layer (C) is 40-800 nm, preferably 60-600 nm, in particular 100-400 nm.

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Suitable materials as high-refractive-index layer are all those mentioned for layer (B).

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Suitable colourless low-refractive-index materials for coating (C) are preferably metal oxides or the corresponding oxide hydrates, such as, for example, SiO_2 , Al_2O_3 , $\text{AlO}(\text{OH})$, B_2O_3 , compounds such as MgF_2 , MgSi_3 , or a mixture of the said metal oxides. The interference system of layer (C) is, in particular, a TiO_2 - SiO_2 - TiO_2 layer sequence.

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Furthermore, the interference pigments according to the invention may also have a semitransparent metal layer as outer layer. Coatings of this type are known, for example, from DE 38 25 702 A1. The metal layers are preferably chromium or aluminium layers having layer thicknesses of 5-25 nm.

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The high-refractive-index layers (B) and/or (C) used can of course also be colourless high-refractive-index materials, such as, for example, metal oxides, in particular TiO_2 and ZrO_2 , which have been coloured with temperature-stable absorbent colorants, such as, for example, red iron oxide or Thenard's Blue. The absorbent colorants may also be applied to the high-refractive-index coating in the form of a film. Berlin Blue and Carmine Red are preferably applied to the pre-calcined TiO_2 and ZrO_2 layers. Examples of coatings of this type are disclosed, for example, in DE 23 13 332.

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Particularly preferred interference pigments are mentioned below:

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- 5 glass flakes + SiO_2 + TiO_2
 glass flakes + SiO_2 + Fe_2O_3
 glass flakes + SiO_2 + Fe_3O_4
 glass flakes + SiO_2 + Cr_2O_3
 glass flakes + SiO_2 + TiO_2 + Berlin Blue
 glass flakes + SiO_2 + TiO_2 + Carmine Red
 glass flakes + SiO_2 + TiO_2 + SiO_2 + TiO_2
 glass flakes + SiO_2 + TiO_2 + Cr
- 10
- 15 mica flakes + SiO_2 + TiO_2
 mica flakes + SiO_2 + Fe_2O_3
 mica flakes + SiO_2 + Fe_3O_4
 mica flakes + SiO_2 + Cr_2O_3
 mica flakes + SiO_2 + TiO_2 + Berlin Blue
 mica flakes + SiO_2 + TiO_2 + Carmine Red
 mica flakes + SiO_2 + TiO_2 + SiO_2 + TiO_2
 mica flakes + SiO_2 + TiO_2 + Cr
- 20
- 25 Al_2O_3 flakes + SiO_2 + TiO_2
 Al_2O_3 flakes + SiO_2 + Fe_2O_3
 Al_2O_3 flakes + SiO_2 + Fe_3O_4
 Al_2O_3 flakes + SiO_2 + Cr_2O_3
 Al_2O_3 flakes + SiO_2 + TiO_2 + Berlin Blue
 Al_2O_3 flakes + SiO_2 + TiO_2 + Carmine Red
 Al_2O_3 flakes + SiO_2 + SnO_2 + TiO_2 + Carmine Red
 Al_2O_3 flakes + SiO_2 + TiO_2 + SiO_2 + TiO_2
 Al_2O_3 flakes + SiO_2 + TiO_2 + Cr
- 30 Of the particularly preferred interference pigments, the coated glass flakes are particularly preferred, furthermore the coated Al_2O_3 flakes.
- 35 The term high-refractive-index coatings is taken to mean layers having a refractive index of > 1.8 , and the term low-refractive-index layers is taken to mean those having $n \leq 1.8$.

The interference pigments according to the invention can generally be prepared relatively easily.

5 The metal-oxide layers are preferably applied by wet-chemical methods, it being possible to use the wet-chemical coating methods developed for the preparation of pearlescent pigments. Methods of this type are described, for example, in DE 14 67 468, DE 19 59 988, DE 20 09 566, DE 22 14 545, DE 22 15 191, DE 22 44 298, DE 23 13 331, DE 15 22 572, DE 31 37 808,
10 DE 31 37 809, DE 31 51 343, DE 31 51 354, DE 31 51 355, DE 32 11 602, DE 32 35 017 or in further patent documents and other publications known to the person skilled in the art.

15 In the case of wet coating, the substrate particles are suspended in water, and one or more hydrolysable metal salts or a water-glass solution are added at a pH which is suitable for hydrolysis, this pH being selected in such a way that the metal oxides or metal oxide hydrates are precipitated directly onto the flakes without secondary precipitations occurring. The pH is usually kept constant by simultaneous metering-in of a base and/or acid.
20 The pigments are subsequently separated off, washed and dried at 50-150°C for 6-18 hours and optionally calcined for 0.5-3 hours, it being possible for the calcination temperature to be optimised with respect to the coating present in each case. In general, the calcination temperatures are between 700 and 1000°C, preferably between 700 and 900°C. If desired,
25 the pigments can be separated off, dried and optionally calcined after application of individual coatings and then re-suspended again for precipitation of the further layers.

30 The precipitation of the SiO₂ layer onto the substrate is generally carried out by addition of a potassium or sodium water-glass solution at a suitable pH.

Furthermore, the coating can also be carried out in a fluidised-bed reactor by gas-phase coating, it being possible correspondingly to use the processes proposed, for example, in EP 0 045 851 and EP 0 106 235 for the
35 preparation of pearlescent pigments.

5 The hue of the interference pigments can be varied in very broad limits through the different choice of the coating amounts or the layer thicknesses resulting therefrom. Fine tuning for a certain hue can be achieved beyond the pure choice of amount by approaching the desired colour under visual or measurement technology control.

10 In order to increase the light, water and weather stability, it is frequently advisable, depending on the area of application, to subject the finished pigment to post-coating or post-treatment. Suitable post-coatings or post-treatments are, for example, the processes described in German Patent 22 15 191, DE-A 31 51 354, DE-A 32 35 017 or DE-A 33 34 598. This post-coating (layer D) further increases the chemical and photochemical stability or simplifies the handling of the pigment, in particular the incorporation into
15 various media. In order to improve the wettability, dispersibility and/or compatibility with the user media, it is possible, for example, for functional coatings of Al_2O_3 or ZrO_2 or mixtures thereof to be applied to the pigment surface. Furthermore, organic post-coatings are possible, for example with silanes, as described, for example, in EP 0090259, EP 0 634 459, WO
20 99/57204, WO 96/32446, WO 99/57204, U.S. 5,759,255, U.S. 5,571,851, WO 01/92425 or in J.J. Ponjeé, Philips Technical Review, Vol. 44, No. 3, 81 ff. and P.H. Harding J.C. Berg, J. Adhesion Sci. Technol. Vol. 11 No. 4, pp. 471-493.

25 Compared with the pigments from the prior art without an SiO_2 layer on the substrate, the pigments according to the invention are distinguished by their higher chroma (tinting strength C^*), their higher gloss (L value) and pronounced glitter effects, in particular in the case of the pigments based on glass or Al_2O_3 flakes. Compared with the goniochromatic pigments from
30 EP 0 753 545 B1, the interference pigments according to the invention exhibit no or only low angle dependence of the colour.

35 Compared with the teaching from WO 01/30920, crucial advantages with respect to gloss and mechanical stability of the pigments according to the invention only arise for SiO_2 as material for the first coating of the support. Beyond the disclosure content of WO 01/30920, silver-white pigments and high-gloss interference pigments having bright interference colours, such

as red, blue or green, are accessible with the invention. The pigments according to the invention can advantageously be blended with absorption pigments or colours owing to their transparency. Combinations of this type enable unusual colour impressions to be achieved in a particularly simple manner.

The pigments according to the invention are compatible with a multiplicity of colour systems, preferably from the area of paints, coatings and printing inks and cosmetic formulations. For the preparation of printing inks for, for example, gravure printing, flexographic printing, offset printing and offset overvarnishing, a multiplicity of binders, in particular water-soluble grades, as sold, for example, by BASF, Marabu, Pröll, Sericol, Hartmann, Gebr. Schmidt, Sicpa, Aarberg, Siegberg, GSB-Wahl, Follmann, Ruco or Coates Screen INKS GmbH, is suitable. The printing inks can be water-based or solvent-based. The pigments are furthermore also suitable for the laser marking of paper and plastics and for applications in the agricultural sector, for example for greenhouse sheeting, and, for example, for the colouring of tent awnings.

Since the interference pigments according to the invention combine high gloss with intense interference colours and highly pronounced glitter effects, particularly effective effects can be achieved with them in various application media, for example in cosmetic formulations, such as, for example, nail varnishes, lipsticks, compact powders, gels, lotions, soaps, toothpastes, in paints, such as, for example, automotive paints, industrial coatings and powder coatings, and in plastics and in ceramics.

Owing to the good skin feeling and the very good skin adhesion, the pigments according to the invention are suitable both for personal care applications, such as, for example, body lotions, emulsions, shampoos, soaps, etc., and, in particular, for decorative cosmetics.

It goes without saying that, for the various applications, the multilayered pigments according to the invention can also advantageously be used in blends with organic dyes, organic pigments or other pigments, such as, for example, transparent and opaque white, coloured and black pigments, and

with flake-form iron oxides, organic pigments, holographic pigments, LCPs (liquid crystal polymers) and conventional transparent, coloured and black lustre pigments based on metal oxide-coated mica and SiO₂ flakes, etc.

5 The pigments according to the invention can be mixed in any ratio with commercially available pigments and fillers.

Fillers which may be mentioned are, for example, natural and synthetic mica, nylon powder, pure or filled melamine resins, talc, SiO₂, glasses, 10 kaolin, oxides or hydroxides of aluminium, magnesium, calcium or zinc, BiOCl, barium sulfate, calcium sulfate, calcium carbonate, magnesium carbonate, carbon, and physical or chemical combinations of these substances.

15 There are no restrictions regarding the particle shape of the filler. It can be, for example, flake-form, spherical or needle-shaped in accordance with requirements.

It is of course also possible for the pigments according to the invention to be combined in the formulations with cosmetic raw materials and assistants of any type. These include, inter alia, oils, fats, film formers, preservatives and assistants which generally determine the technical properties, such as, for example, thickeners and rheological additives, such as, for example, bentonites, hectorites, silicon dioxides, Ca silicates, gelatines, 20 high-molecular-weight carbohydrates and/or surface-active assistants, etc.

The formulations comprising the pigments according to the invention can belong to the lipophilic, hydrophilic or hydrophobic type. In heterogeneous formulations having discrete aqueous and non-aqueous phases, the pigments according to the invention may be present in in each case only one of the two phases or alternatively distributed over both phases. 30

The pH values of the formulations can be between 1 and 14, preferably between 2 and 11 and particularly preferably between 5 and 8. 35

No limits are set for the concentrations of the pigments according to the invention in the formulation. They can be – depending on the application –

between 0.001 (rinse-off products, for example shower gels) and 100% (for example gloss-effect articles for particular applications).

5 The pigments according to the invention may furthermore also be combined with cosmetic active ingredients. Suitable active ingredients are, for example, insect repellents, UV A/BC protective filters (for example OMC, B3 or MBC), anti-ageing active ingredients, vitamins and derivatives thereof (for example vitamin A, C, E etc.), self-tanning agents (for example DHA, erythrulose, inter alia) and further cosmetic active ingredients, such as, for
10 example, bisabolol, LPO, ectoin, emblica, allantoin, bio-flavonoids and derivatives thereof.

15 The pigments according to the invention are furthermore suitable for the preparation of flowable pigment preparations and dry preparations, in particular for printing inks and cosmetic applications, comprising one or more pigments according to the invention, binders and optionally one or more additives.

20 The invention thus also relates to the use of the pigments in formulations such as paints, coatings, automotive paints, powder coatings, printing inks, security printing inks, plastics, ceramic materials, glasses, paper, in toners for electrophotographic printing processes, in seed, in greenhouse sheeting and tent awnings, as absorbers in the laser marking of paper and plastics, in cosmetic formulations, for the preparation of pigment pastes with
25 water, organic and/or aqueous solvents, and for the preparation of pigment preparations and dry preparations, such as, for example, granules.

30 The following examples are intended to explain the invention in greater detail, but without restricting it.

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Examples

Example 1:

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150 g of glass flakes (glass A from Table 1) having an average layer thickness of 700 nm are heated to 75°C with stirring in 1.9 l of deionised water. The pH of the suspension is then adjusted to 7.5 using 5% hydrochloric acid. Sodium water-glass solution (112 g of sodium water-glass solution comprising 26.8% of SiO₂ dissolved in 112 g of deionised water) is subsequently added dropwise, during which the pH is kept constant at 7.5 by simultaneous metered addition of 5% hydrochloric acid. When the addition is complete, the mixture is stirred for a further 0.5 hour. The pH of the suspension is then adjusted to 1.8, the suspension is stirred for a further 15 minutes, and tin tetrachloride solution in hydrochloric acid (3 g of SnCl₄ * 5 H₂O, dissolved in 15 ml of 25% hydrochloric acid and 85 ml of deionised water) is added dropwise, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the addition is complete, the mixture is stirred for a further 15 minutes.

This is followed by metered addition of 30% titanium tetrachloride solution, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. The coloristic properties during preparation of the pigment are monitored by colour measurement during the process, and the precipitation process is controlled in accordance with the hue (hue angle $\arctan b^*/a^*$). When the desired silver end point has been reached, the mixture is stirred for a further 15 minutes. The pigment comprises 20% of precipitated SiO₂, based on the glass flakes.

The product is filtered off, washed, dried at 150°C and calcined at > 700°C.

The finished pigment is incorporated into a commercially available nitrocellulose lacquer, and paint cards are prepared. The paint cards exhibit a very pure silver-white with high gloss.

Table 1: Glass compositions in %

Constituent	Glass A	Glass B
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5	SiO ₂	64	60
	Al ₂ O ₃	5	5
	CaO	6.2	7.7
	MgO	2.2	5.2
	B ₂ O ₃	5.3	6.1
	Na ₂ O + K ₂ O	13.5	16
	ZnO	3.7	0
	FeO/Fe ₂ O ₃	0.1	0
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Example 2:

15 A silver-white pigment is prepared by the process described in Example 1. Instead of glass flakes of composition A from Table 1, glass flakes of composition B having the same thickness and size distribution (20 – 200 µm) are used. The titanium dioxide coating is carried out to the same end point as in Example 1. The pigments obtained cannot be distinguished visually from those from Example 1.

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Examples 3 - 5:

25 Silver-white pigments having the following proportions by weight of SiO₂, based on the glass flakes, are prepared by the procedure indicated in Example 1:

30 Example 3: 2% of SiO₂ by metered addition of 11.5 g of water-glass solution dissolved in 11.5 g of water

Example 4: 5% of SiO₂ by metered addition of 28 g of water-glass solution dissolved in 28 g of water

35 Example 5: 10% of SiO₂ by metered addition of 56 g of water-glass solution dissolved in 56 g of water

The titanium dioxide coatings are carried out to the same hue as in Experiments 1 and 2.

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Examples 6 and 7: (Comparative examples without a first SiO₂ layer)

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150 g of glass flakes of composition A from Table 1 having an average layer thickness of 700 nm are heated to 75°C with stirring in 1.9 l of deionised water. The pH of the suspension is adjusted to pH 1.8 using hydrochloric acid. Tin tetrachloride solution in hydrochloric acid (4.5 g of SnCl₄ * 5 H₂O dissolved in 22.5 ml of 25% hydrochloric acid and 128 ml of deionised water) is subsequently added dropwise, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the addition is complete, the mixture is stirred for a further 15 minutes. This is followed by metered addition of 30% titanium tetrachloride solution, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the desired silver end point has been reached, the mixture is stirred for a further 15 minutes.

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The product is filtered off, washed and dried at 150°C. A sample of the pigment is calcined at 600°C (Example 6), and another is calcined at 700°C (Example 7), in each case for 60 minutes.

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The finished pigments are incorporated into a commercially available nitrocellulose lacquer, and paint cards are prepared using the lacquer. With the pigment calcined at 600°C, the paint cards exhibit a pure silver-white with good gloss, while in the case of the pigment calcined at 700°C, the gloss is significantly reduced.

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Example 8: Comparative example

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150 g of glass flakes of composition A from Table 1 having an average layer thickness of 700 nm are heated to 75°C with stirring in 1.9 l of deionised water. The pH is adjusted to 5.5. 180 ml of aluminium chloride solution

in hydrochloric acid (18 g of aluminium chloride hexahydrate) are added dropwise at 75°C with stirring, during which the pH is held at 5 using sodium hydroxide solution. When the addition is complete, the mixture is stirred at 75°C for a further 2 hours. The coated glass flakes are filtered off, washed, dried at 150°C and dewatered at 400°C for 30 minutes. After cooling, the glass flakes coated with aluminium oxide (about 5% of Al₂O₃) are processed further using titanium by the procedure indicated in Example 6 to give a silver-white pigment.

Compared with the pigment in accordance with the prior art from Example 6, the pigment from Example 8 shows absolutely no improvement in gloss, and compared with the pigments having an SiO₂ layer, the pigment exhibits significantly lower gloss.

Table 2:

Gloss values L and chroma C* of the silver-white pigments from Examples 1-8, measured on a black background

Experiment	Gloss value L	Chroma C*
1	76	3.5
2	76	3.6
3	73	2.16
4	75	2.82
5	76	3.4
6 (comparison)	66	1.9
7 (comparison)	56	1.67
8 (comparison)	62	1.8

Example 9: Testing of the mechanical stability

The abrasion stability of the pigment in cosmetic preparations can be tested in a practical test. It is determined here whether the mechanical stability of a pigment is sufficient for use, for example, in compact powders or creams. As a rapid test, rubbing of a pigment sample with the finger on the palm of the hand has proven successful. In the case of layer detachment or

fracture of the pigment particles by the rubbing, the gloss of the rubbed sample is reduced or completely lost. The decrease in gloss is assessed visually in steps from 1 to 5, where step 1 denotes no change or an increase in gloss during rubbing and step 5 denotes strong matting. Step 3 is regarded as usable to a limited extent for practice, 4 and 5 are regarded as unusable.

The pigments from Examples 1-7 are subjected to an abrasion test of this type. The results are shown in Table 3 and show that only the pigments according to the invention having an SiO₂ layer have adequate mechanical stability for cosmetic applications.

Table 3: Abrasion stability

Pigment	Glass type	SiO ₂ layer	Abrasion stability
Experiment 1 (invention)	A	approx. 70 nm	1
Experiment 2 (invention)	B	approx. 70 nm	1
Experiment 3 (invention)	A	approx. 7 nm	3
Experiment 4 (invention)	A	approx. 17 nm	2
Experiment 5 (invention)	A	approx. 35 nm	1
Experiment 6 (comparison)	A	0	5
Experiment 7 (comparison)	A	0	5

Example 10: (comparative experiment)

100 g of aluminium oxide flakes (prepared as described in EP 0 763 573 B1, Example 2) are suspended in 2 litres of deionised water in a 5 litre laboratory reactor. 200 ml of aqueous SnCl₄ solution (36 g of SnCl₄ per litre of solution) are added dropwise at 3 ml/min at 75°C with stirring. The pH of the suspension is held at 1.8 by metered addition of sodium hydroxide solution. The mixture is stirred for a further 10 minutes, and aqueous titanium tetrachloride solution (125 g of TiCl₄/litre of solution) is then metered in at a rate of 3 ml/min, during which the pH is held at 1.7-1.9 by addition of sodium hydroxide solution. In this way, the aluminium oxide flakes are

coated with a titanium dioxide layer, where, with increasing layer thickness of the titanium dioxide layer, firstly a silver-white and then coloured interference colours of first to third order are formed. The coloristic properties of the interference pigment are measured during the coating process with the aid of a gap-form measurement cell which is connected to the reactor and through which reaction mixture is pumped continuously during the coating. During flow through the gap of the measurement chamber, the pigment flakes are aligned substantially parallel to the flow direction and are measured against a black background. Using a commercially available Minolta CR 300 colour measurement cell, the light reflected at an angle after flash illumination is measured. The measurement data are converted into CIELAB values in accordance with DIN 5033 Part 3 and displayed. In this way, the coloristic properties of the pigment can be determined at any stage of the coating. Figure 1 shows the course of the coloristic properties of the coating in the form of an a^*/b^* diagram. In the system, +a values represent red, -a values represent green, +b values represent yellow and -b values represent blue. The measurement curve begins at the coordinate origin and shows the interference colour corresponding to the titanium dioxide coating. The chroma of the pigments is greater the further the colour location is separated from the coordinate origin.

Example 11:

100 g of aluminium oxide flakes (prepared as described in EP 0 763 573 B1, Example 2) are suspended in 1.6 litres of deionised water in the laboratory reactor from Example 10. The pH of the suspension is set to 8, and sodium water-glass solution (190 g of sodium water-glass solution comprising 26.8% of SiO_2 dissolved in 190 g of deionised water) is subsequently added dropwise, during which the pH is kept constant at 8 by simultaneous metered addition of 5% hydrochloric acid. When the addition is complete, the mixture is stirred for a further 0.5 hour. The pH of the suspension is then adjusted to 1.8 using 5% hydrochloric acid, the mixture is stirred for a further 15 minutes, and tin tetrachloride solution in hydrochloric acid (4.5 g of $\text{SnCl}_4 \cdot 5 \text{H}_2\text{O}$ dissolved in 22.5 ml of 25% hydrochloric acid and 128 ml of deionised water) is added dropwise, during which the pH is

5 kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the addition is complete, the mixture is stirred for a further 15 minutes, and aqueous titanium tetrachloride solution (125 g of TiCl_4 /litre of solution) is then metered in at a rate of 3 ml/min, during which the pH is held at 1.7-1.9 by addition of sodium hydroxide solution. The coloristic properties of the pigment are measured as in Example 10 during the TiO_2 coating. The comparison shows that the pigments according to the invention have significantly better chroma ("tinting strength") than pigments from the prior art (Figure 2). In addition, the pigments according to the invention exhibit significantly higher gloss.

15 Example 12:

150 g of glass flakes (glass C from Table 4) having an average layer thickness of 900 nm are heated to 75°C with stirring in 1.9 l of deionised water. The pH of the suspension is then adjusted to 7.5 using 5% hydrochloric acid. Sodium water-glass solution (112 g of sodium water-glass solution comprising 26.8% of SiO_2 dissolved in 112 g of deionised water) is subsequently added dropwise, during which the pH is kept constant at 7.5 by simultaneous metered addition of 5% hydrochloric acid. When the addition is complete, the mixture is stirred for a further 0.5 hour. The pH of the suspension is then adjusted to 1.8, the mixture is stirred for a further 15 minutes, and tin tetrachloride solution in hydrochloric acid (3 g of $\text{SnCl}_4 \cdot 5 \text{H}_2\text{O}$ dissolved in 15 ml of 25% hydrochloric acid and 85 ml of deionised water) is added dropwise, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the addition is complete, the mixture is stirred for a further 15 minutes.

30 This is followed by metered addition of 30% titanium tetrachloride solution, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. The coloristic properties are monitored during preparation of the pigment by colour measurement during the process, and the precipitation process is controlled in accordance with the hue (hue angle $\arctan b^*/a^*$). When the desired silver end point has been

reached, the mixture is stirred for a further 15 minutes. The pigment comprises 20% of precipitated SiO_2 , based on the glass flakes.

5 The product is filtered off, washed, dried at 150°C and calcined at $> 700^\circ\text{C}$.

The finished pigment is incorporated into a commercially available nitro-cellulose lacquer, and paint cards are prepared. The paint cards exhibit a very pure silver-white with high gloss.

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Table 4: Glass compositions in %

Constituent	Glass C	Glass D
SiO_2	65.7	64.8
Al_2O_3	4.0	4.9
15 CaO	5.9	5.6
MgO	1.9	1.7
B_2O_3	5.4	4.2
$\text{Na}_2\text{O} + \text{K}_2\text{O}$	12.7	14.7
ZnO	4.3	3.9
20 $\text{FeO}/\text{Fe}_2\text{O}_3$	0.1	0.2

Example 13:

25 A silver-white pigment is prepared by the process described in Example 12. Instead of glass flakes of composition C from Table 4, glass flakes of composition D having the same thickness and size distribution (20 – 200 μm) are used. The titanium dioxide coating is carried out to the same end point as in Example 12. The pigments obtained cannot be distinguished visually from those from Example 12.

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Examples 14 - 16:

35 Silver-white pigments having the following proportions by weight of SiO_2 , based on the glass flakes, are prepared by the procedure indicated in Example 12:

Example 14: 2% of SiO₂ by metered addition of 11.5 g of water-glass solution dissolved in 11.5 g of water

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Example 15: 5% of SiO₂ by metered addition of 28 g of water-glass solution dissolved in 28 g of water

Example 16: 10% of SiO₂ by metered addition of 56 g of water-glass solution dissolved in 56 g of water

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The titanium dioxide coatings are carried out to the same hue as in Examples 12 and 13.

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Examples 17 and 18: (comparative examples without a first SiO₂ layer)

150 g of glass flakes of composition C from Table 4 having an average layer thickness of 900 nm are heated to 75°C with stirring in 1.9 l of deionised water. The pH of the suspension is adjusted to pH 1.8 using hydrochloric acid. Tin tetrachloride solution in hydrochloric acid (4.5 g of SnCl₄ * 5 H₂O dissolved in 22.5 ml of 25% hydrochloric acid and 128 ml of deionised water) is subsequently added dropwise, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the addition is complete, the mixture is stirred for a further 15 minutes. This is followed by metered addition of 30% titanium tetrachloride solution, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the desired silver end point has been reached, the mixture is stirred for a further 15 minutes.

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The product is filtered off, washed and dried at 150°C. A sample of the pigment is calcined at 600°C (Example 17), and another is calcined at 700°C (Example 18), in each case for 60 minutes.

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The finished pigments are incorporated into a commercially available nitrocellulose lacquer, and paint cards are prepared using the lacquer. With the

pigment calcined at 600°C, the paint cards exhibit a pure silver-white with good gloss, while in the case of the pigment calcined at 700°C, the gloss is significantly reduced.

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Example 19: Comparative example

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150 g of glass flakes of composition C from Table 4 having an average layer thickness of 900 nm are heated to 75°C with stirring in 1.9 l of deionised water. The pH is adjusted to 5.5. 180 ml of aluminium chloride solution in hydrochloric acid (18 g of aluminium chloride hexahydrate) are added dropwise at 75°C with stirring, during which the pH is held at 5 using sodium hydroxide solution. When the addition is complete, the mixture is stirred at 75°C for a further 2 hours. The coated glass flakes are filtered off, washed, dried at 150°C and dewatered at 400°C for 30 minutes. After cooling, the glass flakes coated with aluminium oxide (about 5% of Al_2O_3) are processed further using titanium dioxide by the procedure indicated in Example 17 to give a silver-white pigment.

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Compared with the pigment in accordance with the prior art from Example 17, the pigment from Example 19 shows absolutely no improvement in gloss, and compared with the pigments having an SiO_2 layer, the pigment exhibits significantly lower gloss.

Example 20: Testing of the mechanical stability

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The testing of the mechanical stability is carried out analogously to Example 9.

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The pigments from Examples 12-18 are subjected to an abrasion test of this type. The results are shown in Table 5 and show that only the pigments according to the invention having an SiO_2 layer have adequate mechanical stability for cosmetic applications.

Table 5: Abrasion stability

	Pigment	Glass type	SiO ₂ layer	Abrasion stability
5	Experiment 12 (invention)	C	approx. 90 nm	1
	Experiment 13 (invention)	D	approx. 90 nm	1
	Experiment 14 (invention)	C	approx. 9 nm	3
	Experiment 15 (invention)	C	approx. 22.5 nm	2
	Experiment 16 (invention)	C	approx. 45 nm	1
10	Experiment 17 (comparison)	C	0	5
	Experiment 18 (comparison)	C	0	5

Example 21:

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125 g of glass flakes (glass D from Table 4) having an average layer thickness of 500 nm are heated to 75°C with stirring in 1.75 l of deionised water. The pH of the suspension is then adjusted to 8 using 5% hydrochloric acid. Sodium water-glass solution (67 g of sodium water-glass solution comprising 26.8% of SiO₂ dissolved in 67 g of deionised water) is subsequently added dropwise, during which the pH is kept constant at 7.5 by simultaneous metered addition of 5% hydrochloric acid. When the addition is complete, the mixture is stirred for a further 15 minutes. The pH of the suspension is then adjusted to 2.8, the mixture is stirred for a further 15 minutes, and about 320 ml of 15% iron chloride solution in hydrochloric acid are added dropwise, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. The coloristic properties of the pigment are measured as in Example 10 during the coating. When the addition is complete, the mixture is stirred for a further 15 minutes. The pigment comprises 10% of precipitated SiO₂, based on the glass flakes.

The product is filtered off, washed, dried at 150°C and calcined at > 700°C.

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The finished pigment is incorporated into a commercially available nitro-cellulose lacquer, and paint cards are prepared. The paint cards exhibit a very pure iron oxide red with high gloss.

Example 22:

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125 g of glass flakes (glass D from Table 4, particle sizes 10 – 60 μm) having an average layer thickness of 500 nm are heated to 75°C with stirring in 1.75 l of deionised water. The pH of the suspension is then adjusted to 7.5 using 5% hydrochloric acid. Sodium water-glass solution (67 g of sodium water-glass solution comprising 26.8% of SiO_2 dissolved in 67 g of deionised water) is subsequently added dropwise, during which the pH is kept constant at 7.5 by simultaneous metered addition of 5% hydrochloric acid. When the addition is complete, the mixture is stirred for a further 15 minutes.

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The pH of the suspension is then adjusted to 1.8, the mixture is stirred for a further 15 minutes, and tin tetrachloride solution in hydrochloric acid (2.5 g of $\text{SnCl}_4 \cdot 5 \text{H}_2\text{O}$ dissolved in 12.5 ml of 25% hydrochloric acid and 70 ml of deionised water) is added dropwise, during which the pH is kept constant by simultaneous dropwise addition of 32% sodium hydroxide solution. When the addition is complete, the mixture is stirred for a further 15 minutes.

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The pH of the suspension is subsequently held at 1.8, and aqueous titanium tetrachloride solution (400 g of TiCl_4 /litre of solution) is metered in at a rate of 2 ml/min, during which the pH is held at 1.7-1.9 by addition of sodium hydroxide solution. The coloristic properties of the pigment are measured as in Example 10 during the TiO_2 coating. When the requisite hue angle has been reached, the pH is adjusted slowly to pH 8 by addition of 32% NaOH, and sodium water-glass solution (9.8 g of sodium water-glass solution comprising 26.8% of SiO_2 dissolved in 9.8 g of deionised water) is again added dropwise, during which the pH is kept constant at 7.5 by simultaneous metered addition of 5% hydrochloric acid. When the addition is complete, the mixture is stirred for a further 15 minutes. The volume of the sodium water-glass solution must be calculated accurately since it is not possible to monitor colour formation in coloristic terms during the coating.

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The pH is then again adjusted to pH 1.8 using 5% hydrochloric acid, and aqueous titanium tetrachloride solution (400 g of TiCl_4 /litre of solution) is

5 metered in at a rate of 2 ml/min, during which the pH is held at 1.7-1.9 by addition of sodium hydroxide solution. The end point of the titration is determined from the hue angle. The pigment comprises 10% of precipitated SiO₂, based on the glass flakes.

The product is filtered off, washed, dried at 150°C and calcined at > 700°C.

10 The finished pigment is incorporated into a commercially available nitro-cellulose lacquer, and paint cards are prepared. The paint cards exhibit a very pure and bright interference colour with high gloss.

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